DREXEL UNIVERSITY
Senior Design
Electrical and Computer Engineering

Progress Report
Winter 2015-2016

Team Number ECE-41

Fetch Drone

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1. Abstract

Everyone has wished at some point, that they didn't have to move to get something. For some, this desire comes from a sentiment of supineness. For others, however, the simple task of getting everyday objects can pose a considerable challenge. This project seeks to help minimize these challenges, regardless of the cause, by providing a flying drone which can deliver objects across a room. The drone shall be of a multirotor design, and shall use image processing techniques to navigate about.

The design includes a specialized hook that will be attached to the object which the user wishes to later retrieve. This allows some abstraction from the particulars of the object being acquired, as the drone must only grasp and hold the hook, bringing along whatever the user has attached to it. The hook will be recognizable by the drone, such that the drone can readily identify it, pursue it, and grasp it, enabling delivery of the hook and attached cargo to the designated location.

In order to keep the scope of the project manageable, the drone shall not be designed for outdoor use, or for navigating amongst rooms indoors. Safety is of the highest importance, and is particularly elevated as flying indoors limits the abilities of the drone to navigate around people. In testing, the prototype drone is always physically restrained. For free flight of the final drone, physical guards will be used to avoid lateral contact with the blades, and the image processing system may attempt to detect moving objects such as people and pets in order to avoid endangering living things. These safety concerns further prompted the likely delivery method of dropping the item from some height above the target, so that the drone itself can remain at a safe distance from any individuals at or near the target.

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2. Problem Statement and Updated Deliverables

While delivery drones are under development by numerous organizations, including both Amazon and Google, there has been minimal development in the space of air-based delivery within the home. For many who struggle with fetching everyday objects from around the house, a delivery drone within the home could be incredibly useful. Similar to the challenge of an external delivery drone, an internal delivery drone must pick items up, transport them, and put them down, navigating amid obstacles along the way. An internal delivery drone also incurs some additional challenges. Within the home, navigation between rooms and around people become a much greater challenge, and safety concerns are heightened. However, this different venue and smaller range also provide different opportunities—the drone can use household Wi-Fi for communication, and could maintain a more thorough map, noting landmarks along the way.

Much of the research and design emphasis for this project will be on the subsystem that handles locating the desired object, as well as the hook subsystem, which must maintain a tight grasp on the cargo until the moment when release is desired.

Location systems that are useful indoors present a significant challenge. Most robots use GPS outdoors, or elaborate systems indoors which are often designed to replicate GPS. Implementing such a system is considered out-of-scope for this project. Thus, the navigational system shall be entirely visual: the drone will know the direction of the target by visually seeing the target. As this imposes a line-of-sight requirement, there will be no attempt to navigate between rooms.

The business of actually picking up an object requires a significant amount of design and engineering work. In order to keep the scope of the project manageable, a hook (part of the project) must be pre-attached to the item that is to be delivered. The hook will provide a predictable, graspable interface for the claw mechanism (the drone portion of the hook system), and will also provide the pattern that will be recognizable by the visual navigation system. The hook system, as a whole, must support the appropriate amount of weight, and must be able to achieve a reasonably firm grasp with imperfect alignments. The hook system is considered a key portion of the design work for this project.

The success of our project should be determined by the ability of our system to bring eligible items to the user without them having to stand up. Note that this does not preclude the user from lifting a finger. It is expected that the user will need to provide some amount of interaction for a safe and complete delivery.

The major system components which provide the general outline for the completion of the project include:

- Construction of a prototype multicoptor which is able to fly. This will provide a test platform for the design of the final drone. This includes the power distribution and regulation system. This component is complete.
- A combination of hardware and software will be assembled which will attempt to keep the drone stable, abstracting the deliberate motions from the stabilization

maneuvers. This component shall be referred to as the Flight Control system. It requires more thorough testing, but is fundamentally complete.

- Development of software which is able to process images from drone-attached cameras in near-real-time, identify a particular pattern, and issue commands to the Flight Control system in order to pursue the target. This component shall be referred to as the navigation system. This component is in development.
- Design and development of the aforementioned hook system, which includes the hook itself (attached to the deliverable item), the claw (attached to the drone), and the pattern which will be recognized by the Navigation system.
- Design and construction of the final drone. The design of this component is pending flexural strength testing of the intended arm material, and requires modifications to the power regulation system in order to provide more regular power to the Flight Control system.

3. Completed Work

The prototype drone is essentially complete and flies competently along a guidewire. It has not been permitted to fly without the guidewire as a matter of safety.

The Flight control system is essentially complete. Consisting mostly of an off-the-shelf purpose-built stabilizing board, the drone is held reasonably stable. Further optimizations and testing are needed, particularly to deal with oscillations within the PID loops when carrying a load.

The Navigation system is still under development. As aforementioned, this is a strictly visual system; hence, it requires a stream of video as an input to the system. Each frame of this stream is passed to a frame segmenter that performs all necessary calculations for that frame. Many image processing techniques utilize mutlitemporal information to improve calculations. One significant challenge, in real time image processing, is designing a frame segmenter that can execute in a short enough amount of time.

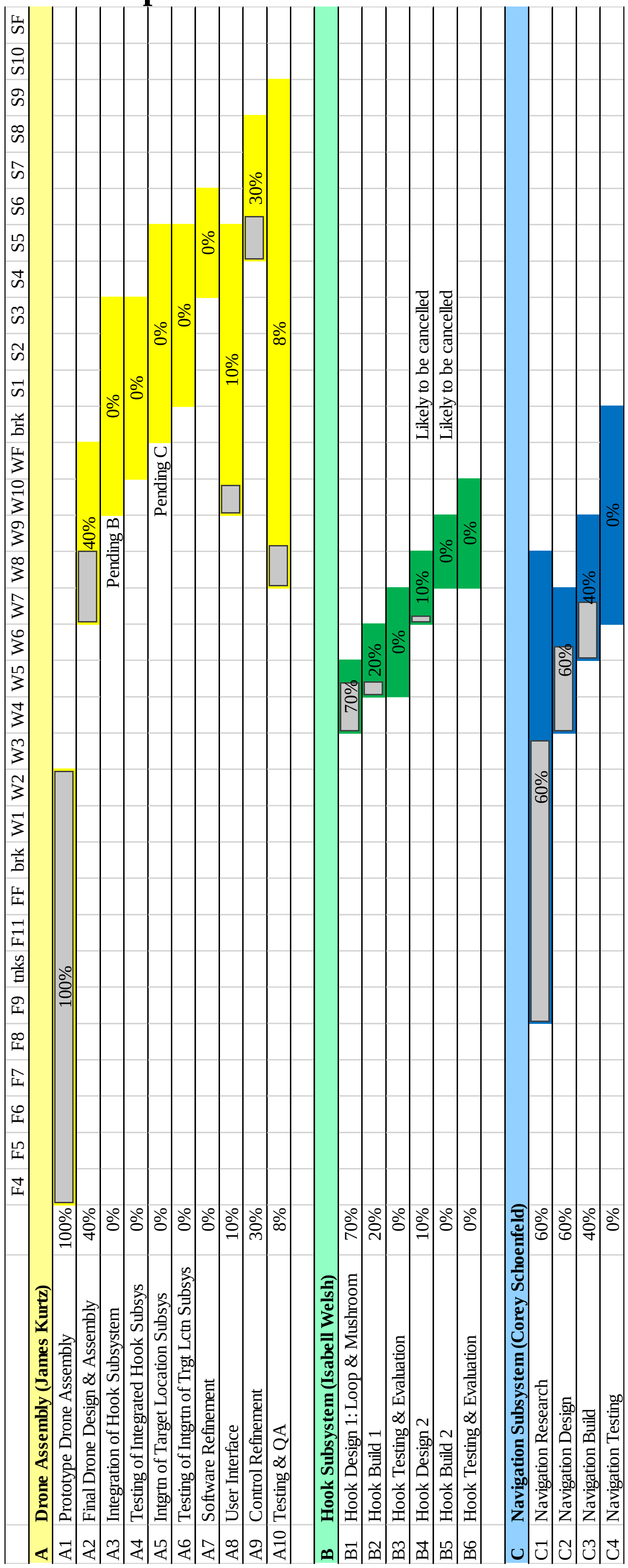
Currently, the frame segmenter is mostly complete. This code can successfully identify dots (LEDS) that a bright relative to their environment. The segmenter also determines the color of each dot. The only expansion required is for the frame segmenter to determine the distances between dots; searching for the existence of a specific dot pattern in the image. Then the location of the pattern in the field of view will be used as information for where the hook is relative to where the drone is facing.

The hook system is in the conception phase of design. The current concept in development is the “tong and mushroom” design discussed last term consisting of a tong-like claw attached to the drone and a knob-shaped hook attached to the target object. The LED's, used for detection of the object, will be arranged on the hook so that the pattern detected by the drone is easily recognizable from all angles. The hook will be designed to be attached to a predetermined object. This severely limits the scope of the project but is necessary for time constraints. The claw will be controlled by a motor. Assembly of a hook system has yet to begin.

The design of the final drone is nearly complete. Compared to the prototype drone, it will be of similar dimensions and will use most of the same electronics, but will be constructed of lighter materials, most notably carbon fiber arms instead of pine. The carbon fiber material intended for this use is currently undergoing flexural strength testing. The electrical distribution system for the final drone, currently modeled on the prototype, needs better regulation in order to supply the processing components more consistently.

This project is notably behind schedule. The proposed timeline (on the next page) has been adapted to represent intended completion scheduling onward.

4. Work Schedule / Proposed Timeline



5. Out-of-Pocket Budget

The out-of-pocket budget below does not yet reflect supplies needed for hook designs or the supplies needed for location and positioning systems, as those systems are still in research phases, and it is not yet clear what they will entail.

This list reflects $383.99 in additional costs incurred since the Fall Progress report.

Item	Cost
Chassis	
.093" Lexan Sheets	$ 17.38
M3 Cap Screws	$ 2.54
#8-32 Zinc-Plated Machine Screw Nut (100)	$ 3.92
#8-32 1-3/4" Machine Screw (50)	$ 5.24
#8 Flat Washers (200)	$ 8.48
Assorted Zip Ties	$ 0.94
Custom-Hewn Pine	$ 12.00
Carbon Fiber Square Tubing (not yet installed)	$ 42.70
Computation & Signal Processing	
35A Fixed Wing Brushless Speed Controller (8)	$ 108.80
KK-Mini Multi-Rotor Flight Control Board	$ 19.99
Raspberry Pi 2B (x2)	$ 77.40
SanDisk Ultra Micro SDHC, 16GB (x2)	$ 20.60
Adafruit 16-Channel PWM Hat for RPi	$ 17.50
Connectors	
3.5mm banana bullet connectors (60 pairs)	$ 19.23
XT60 Connectors (5 Pairs)	$ 5.89
Octocopter Power Distribution Board	$ 11.84
RPi GPIO Stacking Header w/ Extra Long Pins	$ 2.50
3x4 Right-Angle Male Header 4-Pack	$ 2.95
Lead-Free Solder	$ 6.84
Dynamics	
750KV Brushless Quadcopter Motor (11)	$ 215.67
Carbon Fiber Propeller 6x4.5 (4 CW / 4 CCW)	$ 14.84
Carbon Fiber Propeller 13x5.5 (4 CW / 4 CCW)	$ 37.96
Power	
Turnigy 2200mAh 3S 20C LiPo Battery Pack (4)	$ 78.96

DJI Innovations Battery Charger (2)	$ 51.12
Tenergy Balance Charger	$ 57.99
Wiring	
10cm Male-Male Servo Extension Cables (40)	$ 9.99
32cm Male-Female Servo Extension Cables (10)	$ 8.59
16-Gauge Stranded Primary Wire	$ 1.92
Shipping	
DHL from Hong-Kong	$ 20.77
DHL from Liverpool	$ 14.47
UPS from New York	$ 9.55
UPS from New York	$ 9.55
Fedex Ground from Tacoma	$ 19.02
Total	**$ 937.15**

6. Summary/Conclusions

This system is intended as a proof-of-concept for a delivery drone operating within the home. The design team harbors no ambitions for commercializing this device. Thus, some restrictions have been imposed on the design, which would hinder commercial viability, in order to keep the project manageable in scope. Several of these details are explicated in Appendix B: Addressing Comments from the Panel and Appendix A: Design Constraints Summary.

Progress has been unexpectedly slow this quarter. Hopefully, progress will take a more rapid clip during the Spring as the design team faces lighter academic loads.

7. References

[1] (2015). "EyeSight® Driver Assist Technology."
From http://www.subaru.com/engineering/eyesight.html.

[2] (2015). "HobbyKing KK-Mini Multi-Rotor Flight Control Board."
From http://www.hobbyking.com

[3] M. Winter, Andrew R. Cohen. (2015). "Computational Image Analysis Reveals Intrinsic Multigenerational Differences Between Anterior and Posterior Cerebral Cortex Neural Progenitor Cells." Stem Cell Reports.

[4] Rosebrock, A. (2015). "Install OpenCV and Python on your Raspberry Pi 2 and B+." from http://www.pyimagesearch.com/2015/02/23/install-opencv-and-python-on-your-raspberry-pi-2-and-b/.

[5] "OpenCV." from http://opencv.org/.

[6] "Model Aircraft Operations." from https://www.faa.gov/uas/model_aircraft/.

[7] "Cat Tracking using Bluetooth Indoor Positioning." from http://www.instructables.com/id/Cat-Tracking-using-Bluetooth-Indoor-Positioning/.

[8] Parasuraman, R. (2000). "A Model for Types and Levels of Human Interaction with Automation." IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—.

8. Appendix A: Design Constraints Summary

Team Number: ECE-41
Project Title: Fetch Drone

Summary of the Design Aspects:

The major components of the project are:

- A prototype multicoptor, including a system of power distribution and regulation;
- A flight control system in hardware and software which maintains flight, apart from navigational intents;
- The Navigation system, which includes all image processing and alignment procedures;
- The hook system, including the hook proper (affixed to the deliverable item), as well as the claw mechanism (affixed to the drone); and
- The design and assembly of a final drone, with lighter—if less forgiving—materials, and a more robust power system based on lessons learned in the prototype.

Within each of these major components, some testing procedures are already in-use (such as those intended for testing load-bearing abilities), and others are under development (such as the procedure for evaluating the effectiveness of the navigational system. Also, safety shall be integrated into all design decisions where feasible.

Due to the novelty of a delivery drone for the indoors, there are relatively few standards and guidelines available with which we could comply. Also, as the design team harbors no ambitions of commercial viability, compliance with consumer electronic standards is considered an out-of-scope luxury.

Design Constraints:

Economic:
Prebuilt drones capable of carrying the intended amounts of weight are well above planned cost levels. However, the duplication of some materials caused by first building a prototype drone, as well as the costs incurred for test and development equipment have elevated the total out-of-pocket project cost to levels approaching those of a prebuilt system.

Manufacturability:
The construction methods used throughout these designs are labor and time-intensive. Thus, this project is generally not being considered commercially viable for large-scale production. Conveniently, the design team of this project harbors no ambitions of commercialization. Methods include general machining for the construction of the drone, the soldering and assembly of custom power distribution systems, and 3D printing for creating the hook.

Sustainability:
Due in large part to the intentional lack of commercial viability in this project, the impacts imposed by intents of sustainability have been found to be essentially negligible. The

project management of this project thus far, however, should not be considered sustainable in any way.

Environmental
Due in large part to the intentional lack of commercial viability in this project, the environmental impacts have been found to be essentially negligible.

Ethical, Health, and Safety
Ethical dilemma surrounding camera-equipped drones abound. However, the present design does not have any considerations for making imagery from the camera available to any user; images are consumed by the navigational system and are not saved to any file or network system.

Health and Safety
At full speed, the tips of the rotors move at about 290 miles per hour. As these rotors are made of carbon fiber, and have enough mass to slice through human skin, safety is s rather substantial concern. The prototype drone has only been permitted to fly along a guidewire, making the spinning blades readily avoidable. The final drone currently in development will include a ring around the full perimeter intended to act as a physical bumper, physically preventing collisions with persons and property.

Social
Due in large part to the intentional lack of commercial viability in this project, the social impacts have been found to be essentially negligible.

Political
Due to the intentional use of this project indoors, there are currently no legal restrictions imposed upon this project.

Standards and Regulations
Since this drone is meant for indoor use only, it is not subject to flight regulations that apply to most outdoor drones or commercial aircraft.

The communications methods employed by this project are limited to Wi-Fi. These connections are maintained by off-the-shelf, standards-compliant network interfaces.

The design team harbors no ambitions of commercializing this project. If, however, it was to be commercialized, it would require substantial redesign efforts in order to comply with the regulations that would be imposed upon it as a device similar to a toy or other consumer electronic device.

Scope Consolidation
A few substantial design decisions have been made in order to keep the scope of this project relatively manageable. The most substantial ones are given below.

Visual Navigation Only
The drone shall only use visual indicators in order to detect a target, for both pickup and delivery. This removes any possibility of pickup or delivery beyond line-of-sight.

Hook Attachment
All deliverable objects shall have a hook attached, which provides a pattern recognizable by the navigational system, and a design readily capable of being grasped by the claw mechanism attached to the drone. This removes any possibility for grasping items which may not have this hook attached.

Indoor Use Only
So far, the drone is sufficiently compliant with regulations necessary for outdoor flight. However, as maintaining that compliance is not a deliberate design objective, the drone shall only be used indoors, where such projects are unrestricted.

9. Appendix B: Addressing Comments from the Panel

Each of the particular comments which were legible are noted and addressed below.

"This should not be primarily a tool that advocates laziness" and "Direct toward disabled persons" and "Characterize as a device to help the disabled."

All written explanations (most notably, the Abstract) have been rewritten or substantially adjusted with the aim of better highlighting the potential for this project to assist those who may be physically unable to fetch things themselves.

"This looks dangerous" and "What about Safety?"

With the prototype drone, safety continues to be a considerable concern. There are still no guards around the blades. However, this is still the *prototype* drone. The final drone design includes a ring around the full circumference outside the sweep of the blades, intended to avoid lateral collisions with the blades. The prototype drone has never, and will never, be permitted to fly without a guidewire.

Ultrasonic proximity sensors are also being tested for potential use, but early results haven't been particularly promising—the rotors appear to cause an interesting case of the Doppler effect.

"The Design is Extremely Limited" and "Limited Scenario as a result of mounting the hook on the desired object."

These comments are entirely legitimate, and are an intentional part of the design in order to keep the scope of the project manageable. Certainly, such a drone would be more useful if it were capable of recognizing and fetching untagged everyday objects. However, this has been deemed unrealistic to accomplish within the amount of time allotted for this project.

"Mention the limitations of the Designed Drone."

The "Design Constraints" section has been largely rewritten with the intention of making these clear. The approach taken for the presentation will be likewise adapted.

"How practical is it to have hooks on the objects to pick up?"

Not at all. For all practical purposes, "practicality" is not the best measure of this project. Many design decisions have been made which are largely impractical in the "real world," but which are important for reducing the scope of the project to a relatively manageable size.

"Missing Runners"

It is assumed that this was a comment on the prototype's previous lack of feet. The prototype drone currently is only flown along a guidewire which has a landing pad at the bottom, making feet currently unnecessary. However, feet are included in the design of the final drone, which will fly without a guidewire.

"Navigation around unexpected objects?"

Anything unexpected is largely considered out-of-scope. We realize that's a scoping decision that is utterly unfathomable outside of the 'lab' environment. However, such restrictions are imperative for an on-time delivery, which is the single greatest scope consideration for this project.

In theory (not by design specification), the drone can only pursue objects it can "see". Thus, if an unexpected object blocks its sight, it would be expected to stop pursuit. Should a collision occur, the blade guards of the final drone should prevent injury to person and property.

"This is going to be a tough project to complete; Narrow the scope."

We concur. Presently, we hope our final deliverable is able to pick things up, carry them, and put them down *with some amount of human control.* This removes much of the complexity of an entirely-autonomous navigation system.

"Consult someone about computing lift."

Done. PhD candidate MechE friends are fantastic. Calculations can be found in the notebook.

10. Appendix C: Individual Contributions to the Project

Each member is listed with their name and the general area for which they were responsible. Particular contributions made by the individual, which have been realized in the assembled system, are then bulleted.

James Kurtz – Drone Assembly & Flight Control

- Completion of prototype drone chassis and flight system. It flies!
- Design of final drone hardware is nearly complete; pending flexural strength testing of carbon fiber tubing intended for the arms.
- Functionally completed interface which will enable the image processing system to issue somewhat abstracted flight control commands. Still needs extensive testing and optimization.
- Initial development of HTTP JSON control interface intended to eventually provide user control.
- Completed an initial power distribution system. This needs to be redesigned to better regulate power to the Raspberry Pi.

Corey Schoenfeld – Navigation System

Isabell Welsh – Hook System

Fetch Drone

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Objective

Build a multicopter that can fly and can carry a load of several pounds.

Design a navigational system that allows the drone to locate potential cargo, and the delivery location.

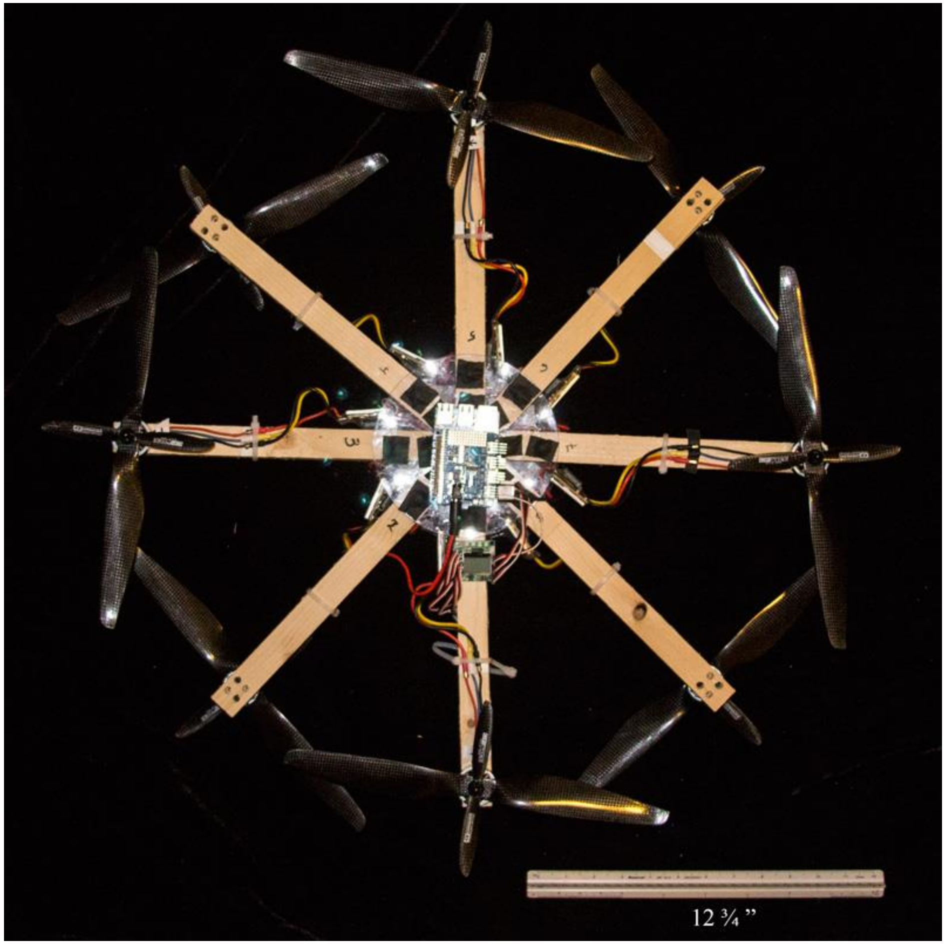
Design a hook system that wherein a hook can be suitably attached to potential cargo, and grasped and carried by the drone.

Approach

1. Borrow and adapt multicopter designs that hobbyists have successfully used to build a prototype drone,
2. Develop hook system
3. Develop navigational system,
4. Design and build final drone with lessons learned from prototype

Key Milestones

• Initial Drone assembly	11/15
• Flight Control System	02/16
• Hook Prototype (Design 1)	03/16
• Navigation System	03/16 (Projected)
• Hook Prototype (Design 2, if needed)	03/16 (Projected)
• Final Drone Assembly	04/16 (Projected)
• User Interface Software	04/16 (Projected)



The prototype drone with rotors. Hook system not yet attached. Battery and portions of power system not shown.